NITRATE DEPOSITS IN SOUTHERN IDAHO AND EASTERN OREGON.

By G. R. MANSFIELD.

INTRODUCTION.

The nitrate deposits near Homedale, Idaho, appear to have been first discovered in the spring of 1914 by D. J. Sullivan, of Homedale, who, according to his own account, recognized their occurrence in the canyon of Jump Creek about 10 miles south of Homedale in proximity to an old metalliferous prospect just below the falls of that creek. Only a small quantity of the material was found, "enough to fill two flour sacks," but a strip of brown paper dipped in a solution of the substance and then dried and burned indicated by its sputtering scintillations the presence of a nitrate.

About the same time the young sons of George D. Huntley, whose ranch lies in the canyon of Sucker Creek about 10 miles west of the Jump Creek locality, were playing in a small cave at the base of a cliff in the canyon about half a mile below their home. Having started a fire in the cave, they were surprised to find that some of the white material at the back of the cave and in the crevices of the rock took fire and burned vigorously. This incident, together with the discovery by a camping party of a white deposit at several localities on Sucker Creek, was reported to Mr. Sullivan, who visited the place and again recognized the presence of a nitrate in the deposits. Meanwhile a prospector named Lacky who had passed through Sucker Canyon had collected a sample of the white material and had shown it to persons in Ontario, Oreg., among whom chanced to be Henry Wilson, a California mining engineer, who recognized the presence of a nitrate in the sample.

Mr. Sullivan and his associates staked out claims, and shortly afterward interested persons from Ontario made extended examination of the district and rapidly staked out a large area, so that considerable local excitement ensued. At the time of the writer's visit (November, 1914), however, no assessment work had been done except by Mr. Sullivan and his associates.

The writer wishes to express his appreciation of the kindness extended to him by Mr. Sullivan, who conducted him to the several localities where the interesting deposits of the district could be best seen, and tendered him the hospitality of both camp and home. Thanks are due also to Messrs. F. E. and W. Tracy for courtesies in camp.

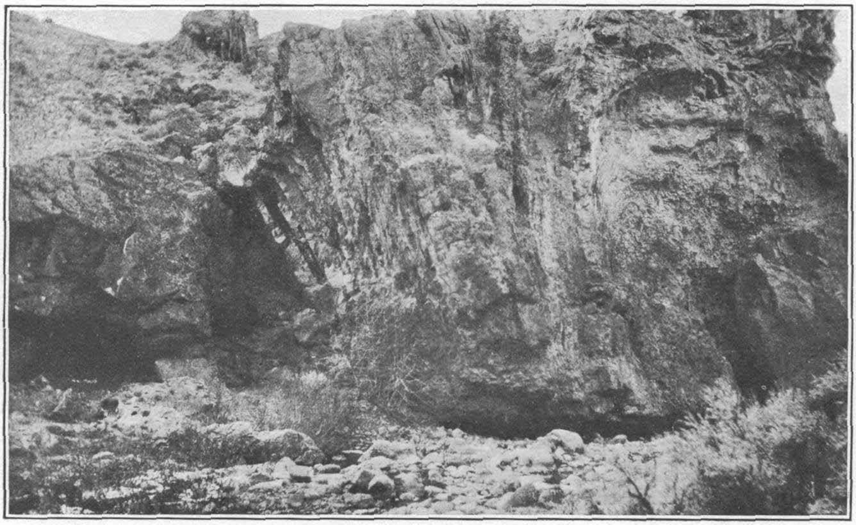
Mr. J. F. Hunter, jr., of the Geological Survey, has been kind enough to examine and discuss with the writer several thin sections of rocks from this region. The analyses of the samples were made in the laboratories of the Geological Survey by Mr. R. K. Bailey.

HOMEDALE DEPOSIT.

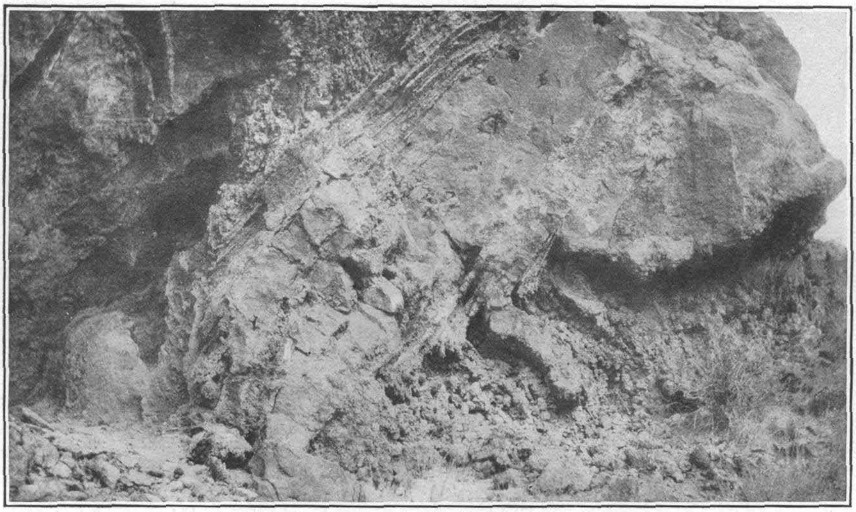
GENERAL FEATURES.

The Homedale nitrate deposit is located in and near the canyon of Sucker Creek, Oreg., about 16 miles in a direct line southwest of Homedale, Idaho (fig. 2), but the distance by the usual road is nearly 26 miles. With two exceptions the locations of claims and prospects on the map are approximate, because it proved to be impracticable to tie these locations to established land corners. The location of Huntley's ranch is taken from a legal description of the property placed in the writer's hands by Mr. Sullivan after the completion of the examination. The location of the American placer claim was fully set forth in the location notice at the discovery stake and prospect. The other location notices observed did not contain specific reference to established land lines. The Sucker Creek prospects are located with reference to Huntley's ranch and the Jump Creek prospects with respect to the topography shown on the map of the Silver City quadrangle published by the Geological Survey. Nitrate was originally discovered in this region in the canyon of Jump Creek about 10 miles south of Homedale, immediately below the falls in that canyon. The deposit in the Jump Creek locality, however, appears to have been exhausted with the first prospecting. In both localities the mode of occurrence of the nitrate is the same.

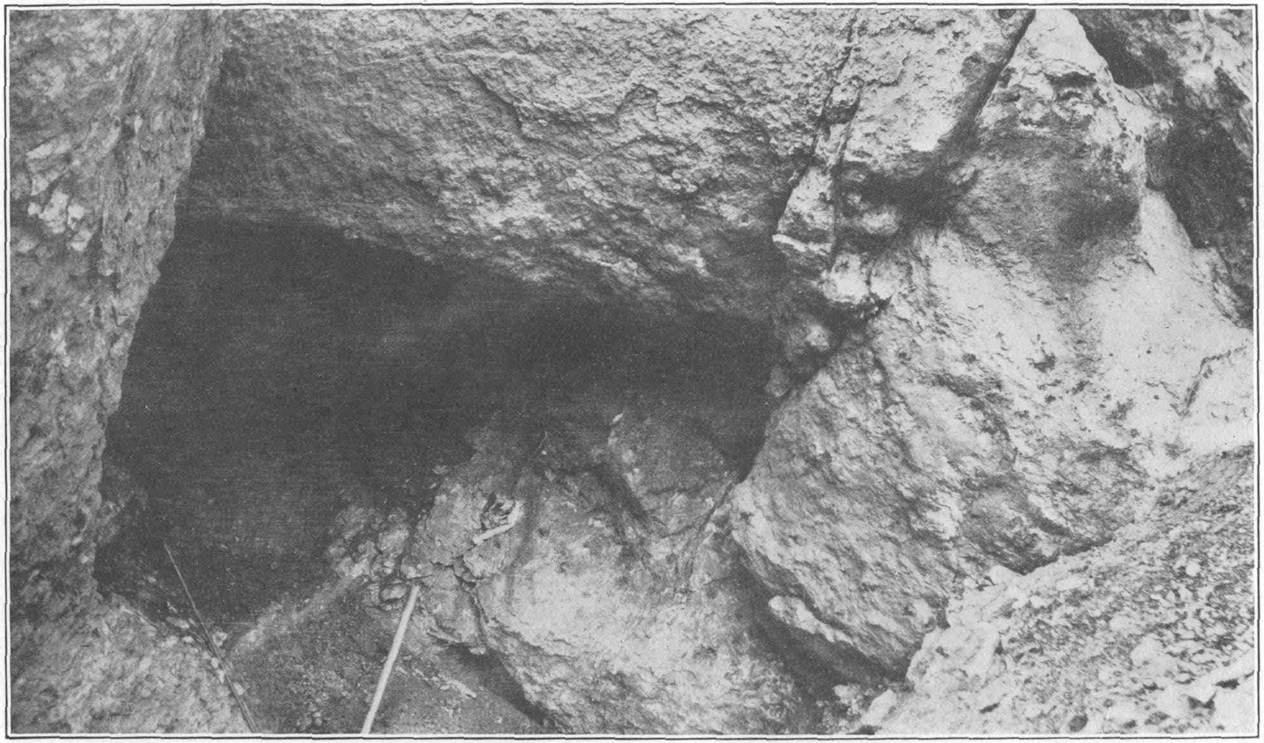
The rhyolite in which the canyons are cut forms vertical or overhanging cliffs. Along the bases of the cliffs there are local recesses or tiny caves. (See Pl. II.) Much of the rhyolite is close textured and massive, but there are zones where the rock is more open textured and shows pronounced banding and spherulitic structure together with some brecciation. Associated with these zones are certain bands, more massive than the others, that contain scattered vesicles, 2 to 6 inches in diameter, many of which are in part or wholly filled with opal, agate, or chalcedony. These vesicles give a blotchy appearance to the rock forming the cliffs. At these places also the rocks have a more or less shelly structure, so that fractures penetrate the rock in many directions and angular pieces 3 to 6 inches or more long and 1 to 3 inches thick are readily dislodged. (See Pls. II, III.)



A. CONTORTED FLOW STRUCTURE IN THE RHYOLITE ON THE WEST WALL OF SUCKER CANYON, OREG.



B. CONTORTED FLOW STRUCTURE IN THE RHYOLITE ON THE EAST WALL OF SUCKER CANYON, OREG.



PROSPECT AT THE ABBIE CLAIM ON HUNTLEY'S RANCH, OREG.

ABBIE CLAIM.

At the Abbie claim, on Huntley's ranch, this shelly zone is nearly 50 feet wide. The vesicles are partly filled with a green mineral, which is also disseminated to some extent through the rhyolite. In thin section, under the microscope, the rhyolite appears to be normal in composition, showing phenocrysts of quartz and feldspar having

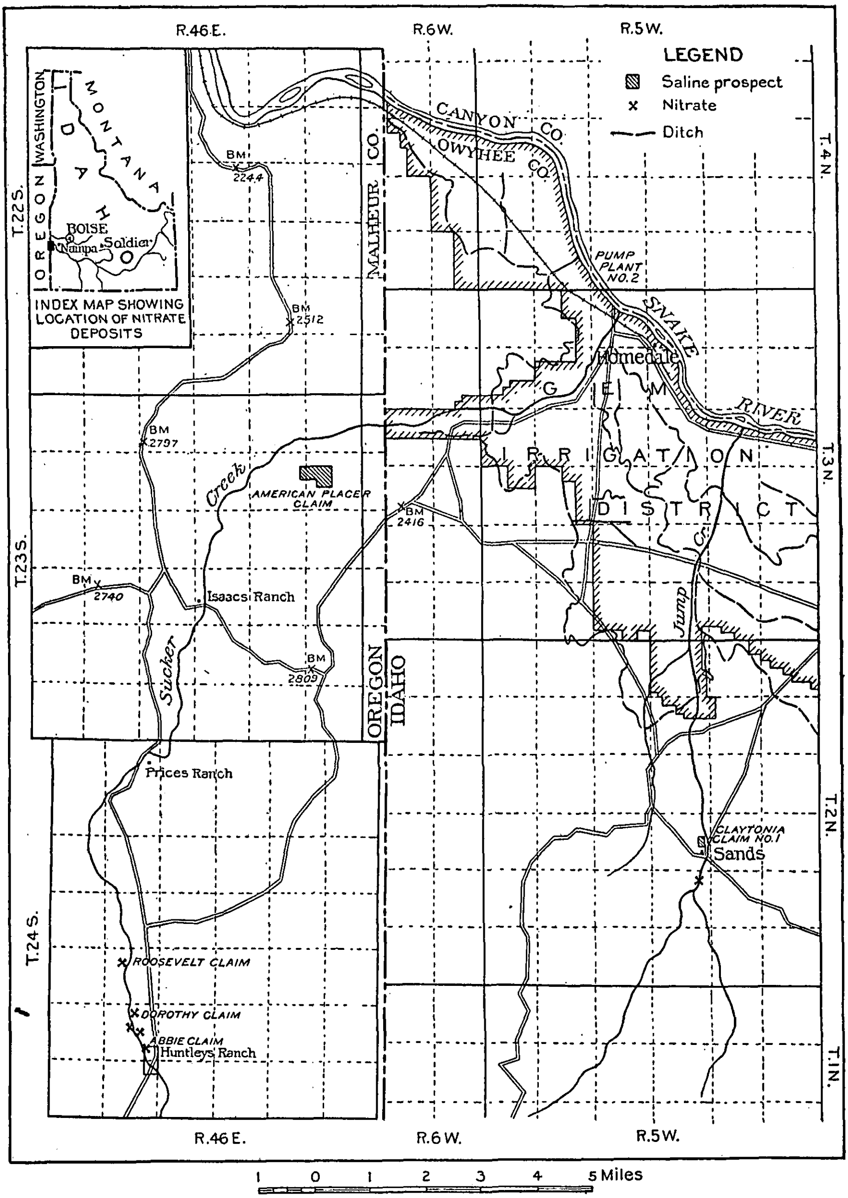


FIGURE 2.—General map of the nitrate field near Homedale, Idaho, with index map showing the location of the Homedale and Soldier deposits.

maximum diameters of about 4 millimeters in a fine cryptocrystalline groundmass of quartz and orthoclase with a few specks of iron ore and a little chlorite. The green mineral is not differentiated by its refractive index from the surrounding rock and appears to be chalcedony. The color is apparently little more than stain, though fine particles of chlorite may be present.

In the cracks and crevices of the rock are veinlets of white, finely crystalline material which burns with a sparkling flame when a lighted match is applied to it and causes the glowing tip of the match to burn brightly at white heat. The veinlets are in general about one-eighth to three-eighths of an inch thick. When the fractured rock is picked away fresh seams or veinlets of the white deposit are exposed, but these, like the others, are only a fraction of an inch thick, and much of the deposit is so loosely aggregated that it crumbles and falls to the soil below when the shelly rock is disturbed. Samples of this material appear on analysis in the laboratories of the Geological Survey to consist essentially of potassium nitrate and sodium nitrate. (See p. 26.) Associated with the nitrate in the same or adjacent crevices is a somewhat harder and more firmly aggregated white mineral in fairly coarse fibrous or prismatic form. On analysis this material appears to consist essentially of the sulphates of sodium and magnesium. The zone in which these crevice deposits occur is not sharply defined but has a width of 3 or 4 feet. No distinct vein of the material is to be seen.

The nitrate tends also to accumulate in the border zone between the soil and the bases of the cliffs and can be exposed by scraping away the soil. It was reported that at the time of the discovery this material at the soil line was plentiful enough to be shoveled into buckets. This excess seems to have been removed, and only whitened soil and a scant white deposit are now found in this position. At this claim an opening about 10 feet long, penetrating the cliff face about 4 feet and extending along the nitrate-bearing zone for about 8 feet, had been made at the time of the writer's visit.

DOROTHY CLAIM.

At the Dorothy claim, situated about half a mile north of Huntley's ranch, at the base of the cliff on the east side of Sucker Creek, a pit about 8 feet long, 7 feet deep, and 3 feet wide has been opened. The face of the recess or cave has also been picked down a few inches or perhaps a foot. This is the locality at which the Huntley children discovered the inflammable nature of the deposit. The material at this claim is similar in nature and mode of occurrence to that of the Abbie claim. The width of the zone in which the veinlets occur is indeterminate but does not seem to exceed 3 feet. The veinlets themselves range from one-sixth to three-eighths of an inch in thickness and occur in crevices between the rhyolite blocks. The sodium and magnesium sulphates in their coarse fibrous form occur in the same veinlets with the nitrate, which is here sodium nitrate, and in adjacent veinlets. The material at the soil line, which was reported to have been fairly abundant, has been largely removed, so that, as in the Abbie claim, only a whitened soil and a scant white deposit were to be seen in that position at the time of the writer's examination.

About 300 feet north of the Dorothy claim on the west wall of the canyon there is a white incrustation of small extent on the face of the cliff. This material has a sharp, puckery taste, resembling that of alum. A qualitative test shows it to consist essentially of the sulphates of alumina and magnesia. Some potassium is indicated in the analysis, but although a little of the potash alum may be present the composition of the substance is nearer that of pickeringite, the formula of which is $MgSO_4.Al_2(SO_4)_3.22H_2O$.

OTHER PROSPECTS.

Several prospects and numerous unprospected claims lie along Sucker Creek as well as east and west of the creek north of Huntley's ranch. The mode of occurrence and character of the deposits on these claims were similar to those above described. Samples were collected from only one, the Roosevelt claim, about 1½ miles below Huntley's ranch. Here only a small beginning at prospecting had been made, and the evidences of nitrate deposits were not as abundant as at the Abbie and Dorothy claims. Both the loosely aggregated nitrate and the more firmly aggregated fibrous mineral were present, however, and samples of each were collected for analysis. The samples were taken from the line of contact of the soil with the base of the cliff, by scraping away the soil. The nitrate deposit on qualitative analysis proves to be somewhat less pure than those already described, consisting of some potassium nitrate with admixtures of magnesium and sodium sulphates. The accompanying fibrous mineral, which showed no reaction with the match flame, contains magnesium sulphate, sodium chloride (common salt), and sodium nitrate.

At the same locality there was in places a pronounced red incrustation on the rock that had a pungent taste. A sample of this substance was collected and submitted to qualitative analysis. The soluble portion was found to consist essentially of sodium chloride and potassium nitrate, with some calcium nitrate and sodium sulphate. The insoluble portion of the coating was found to consist essentially of iron oxide (Fe_2O_3) with small amounts of the carbonates of calcium and magnesium.

Perhaps half a mile below the Roosevelt claim cracks in the face of the cliff contain common salt in somewhat greater abundance than at the localities previously noted. This spot has been discovered by cattle and horses that range in the vicinity of the canyon, as shown by the accumulation of manure at that place.

About 3½ miles below Huntley's ranch, at the foot of the canyon wall, on the east side of the canyon, there is a small spring. The temperature of the spring appears to be only slightly if at all above normal. The waters that supply the spring and seep from neighboring cracks are sufficiently charged with soluble salts to produce by evaporation a thin incrustation upon the adjacent rocks and also on bowlders in the bed of Sucker Creek for a short distance above and below the spring. The water, though slightly saline, is not unpleasant to the taste and in moderate amounts at least appears to produce no unpleasant effects after drinking. A small sample of the contained salts was obtained by scraping away with a knife some of the incrustation in the immediate vicinity of the spring. This powdery white substance fluxed readily in the match flame, but gave no suggestion of the presence of a nitrate. On qualitative analysis it proved to consist essentially of sodium sulphate with some magnesium sulphate.

The conditions in the canyon of Jump Creek, 10 miles east of Sucker Creek, are similar in the main to those along Sucker Creek. The walls of the canyon are formed of weathered and pinnacled rhyolite with cavernous recesses at the bases of the cliffs. Large bowlders and irregular masses of rock, which have fallen from the surrounding cliffs, obstruct the canyon and add to its wildness and picturesque appearance. Zones of shelly rhyolite with coarse scattered vesicles occur here, as on Sucker Creek. The caverns show a white incrustation, and many of the crevices have a white filling which melts but does not burn or sputter in the match flame. A sample of this salt gathered from a 2-inch zone along the soil line at the base of a little cavern in a large loose piece of rhyolite about a quarter of a mile below the falls proved on analysis to consist essentially of magnesium and sodium sulphates with some sodium chloride.

Just below the falls there is a ferruginous zone 2 to 3 feet wide along which and to the north of which the rock is much fractured. A short opening has been made in this ferruginous zone, and on the west, where the rock is more solid, an old tunnel has been driven in that direction some 60 feet. Just above this ferruginous prospect and in the fractured rock there is a little recess that has been deepened by picking. This is the place in which Mr. Sullivan made the first nitrate discovery in the district. The nitrate material seems to have been entirely exhausted, but the crevices contain a white, coarsely fibrous or prismatic crystalline salt in veinlets one-eighth to three-fourths of an inch wide, with a strong puckery taste, resembling that of alum. A qualitative test, however, fails to show the presence of any significant amount of potassium, while aluminum, magnesium, and sodium are present in abundance. The substance is essentially a combination of the sulphates of the three last-named elements.

ANALYSES.

In order to get general information about the character of the samples from the Homedale district, a series of qualitative tests was first made. On the evidence afforded by these tests a selection was made of two samples of the nitrate which were regarded as representative of the group, and these were subjected to quantitative analysis. The results of some of the qualitative analyses have been mentioned above, but all these analyses are given on page 26 in tabular form for comparison and convenience of reference.

Qualitative analyses of samples from the Homedale district, Oregon and Idaho.

Field No. of specimen.	Locality.	Cl.	SO_4.	CO_3.	NO_3.	K.	Na.	Ca.	Al.	Mg.	Essential composition.	Remarks.
	OREGON.											
S. C. 1	Spring 3½ miles below Huntley's ranch.	None	Much	Small amount.	None	None	Much	Very little.		Fair	Na_2SO_4 with some $MgSO_4$.	Salt incrustation around spring.
S. C. 3	Dorothy claim	do	do	do	Good test.	None or trace.	do	Very small.		Much	$NaNO_3$ and Na_2SO_4	Discovery Cave on Sucker Creek.
S. C. 4	Abbie claim	do	Some	None	do	Much	do			Trace	KNO_3 and Na_2SO_4	
S. C. 5	About 300 feet north of Dorothy claim, on west wall of canyon.	do	Much	do	None	Some	do		Much	Much	Sulphates of aluminum and magnesium.	Incrustation supposed to be alum, but more closely allied to pickeringite $MgSO_4.Al_2(SO_4)_3.22H_2O$.
S. C. 6	Roosevelt claim	Small amount.	Some	do	Much	Small amount.	do	Some		do	$NaNO_3$, $Mg(NO_3)_2$, and $Ca(NO_3)_2$.	Better-grade material from prospect.
S. C. 7	do	Much	Small amount.	do	do	None	do	None		Some	$MgSO_4$, NaCl, and $NaNO_3$.	Fibrous mineral accompanying better nitrate.
S. C. 7a	do	do	Some	do	do	Some	do	Fair		Small	NaCl, KNO_3, some $Ca(NO_3)_2$, and Na_2SO_4.	Red incrustation, soluble part. Insoluble red material essentially Fe_2O_3 with possibly $CaCO_3$ and $MgCO_3$.
S. C. 8a	American placer claim.	None	Much	do	None	None	do	Small amount.		Very small.	Na_2SO_4 with some $MgSO_4$.	White efflorescent material near surface.
S. C. 8b	do	Small amount.	do	do	do	Some	do	do		Large amount.	$MgSO_4$, Na_2SO_4, and some NaCl.	Coarse crystalline deposit 2½ to 3 feet below surface and impregnated with clay.
	IDAHO.											
S. C. 9	Claytonia claim No. 1.	Some	do	do	do	do	do	do		do	$MgSO_4$, Na_2SO_4, and NaCl.	Coarse crystalline deposit, 10 inches more or less.
S. C. 9a	do	do	do	do	do	None	do	do		Much	$MgSO_4$ and Na_2SO_4	4 inches of yellow sand below S. C. 9.
S. C. 9b	do	do	do	do	do		do			do	NaCl, $MgSO_4$, and Na_2SO_4.	Gray sand below S. C. 9a, 18 inches.
S. C. 10	Jump Creek nitrate prospect.	None	do	do	do	None or trace.	do	None	Much	do	$Al_2(SO_4)_3$, $MgSO_4$, and Na_2SO_4.	Coarsely fibrous mineral in veinlets $\frac{1}{16}$ to $\frac{3}{4}$ inch wide.
S. C. 11	Jump Creek about one-fourth mile north of nitrate prospect.	Good test.	do	do	do	Trace or none.	do	do		do	$MgSO_4$ and Na_2SO_4	Incrustation on walls of tiny cave in large loose rock.

Complete quantitative analyses were made of two of the samples, Nos. S. C. 3 and S. C. 4, and a determination of the nitric acid in sample S. C. 6 was made. The results of these analyses are given in the following table:

Analyses of samples of nitrates from Sucker Creek, secs. 20 and 29, T. 24 S., R. 46 E., Willamette meridian, Oreg.

[R. K. Bailey, analyst.]

	S. C. 3 (Dorothy claim).	S. C. 4 (Abbie claim).	S. C. 6 (Roosevelt claim).
Cl	0.09	0.18	
SO_4	19.39	4.62	
HCO_3	None.	None.	
CO_3	None.	None.	
BO_3	None.	None.	
NO_3	47.25	59.91	73.75
Na	31.13	13.74	
K	.39	19.75	
Mg	.14	.03	
Ca	1.61	1.77	
	100.00	100.00	
Soluble portion (per cent of dry sample)	90.50	98.06	

On the assumption that the NO_3 in sample S. C. 3 is practically all combined with the Na, it is computed that the soluble portion of the dry sample contains 64.7 per cent $NaNO_3$ (sodium nitrate), equivalent to 58.5 per cent sodium nitrate in the entire sample.

On the assumption that all the NO_3 in sample S. C. 4 is combined with the K or Na, although a small amount may be combined with the Ca, it is computed that the soluble portion of the dry sample contains 50 per cent KNO_3 (potassium nitrate) and 40.6 per cent $NaNO_3$ (sodium nitrate), or 90.6 per cent total nitrates, equivalent to 88.8 per cent of the entire sample.

In sample S. C. 6 the other constituents besides the NO_3 were not determined, but from the combining weights of the elements concerned and the qualitative analysis given on page 26 it is assumed that the nitrates are in the form of sodium nitrate with probably magnesium or calcium nitrates and little if any potassium nitrate. The total nitrates probably exceed 90 per cent.

Samples S. C. 4 and S. C. 6 compare favorably with the best grades of nitrate reported from various western sources. They represent, however, selected material from their respective localities. Sample S. C. 3 is more nearly representative of the character of the deposit as a whole, because it contains a higher percentage of the sulphates which are present in each of the localities examined. In any attempt to work the deposit on a commercial scale it would be difficult if not impracticable to separate the nitrates from the sulphates that occur in the same and adjacent veinlets, so that it is probable that an average lot of the material from the entire Homedale district would not run higher than the 58.8 per cent sodium nitrate of the dry sample S. C. 3 and it might even run lower. This figure, however, is higher than that for the better grades of saltpeter mined in Chile. (See p. 40.)

SOLDIER DEPOSIT.

MODE OF OCCURRENCE.

A number of samples of nitrate salts with accompanying pieces of country rock from a locality described as 9 miles east of Soldier, Idaho, and 9 miles north of the railroad, have recently been sent to the Geological Survey by Mr. John Finch. Soldier is in Blaine County, in T. 1 N., R. 14 E. Boise meridian. (See fig. 2, index map.)

The country rock is a rhyolite, which in thin section under the microscope appears much like the rhyolite at Homedale, except that it is somewhat more glassy and badly weathered. The rhyolite specimens show the same tendency to spherulitic texture and shelly structure that is possessed by the Homedale rock. The nitrate salts occur in depressions or small cavities in the rhyolite, and also impregnate the soil in certain places, probably at the bases of cliffs, as at Homedale. No examination of this locality has yet been made by the Geological Survey, but a study of the samples suggests that the mode of occurrence of the nitrate near Soldier is similar to that near Homedale. According to Mr. Finch there is a considerable quantity of the material readily accessible.

ANALYSES.

The samples from Soldier had broken loose in the sack in transit and had mingled to a certain extent. Four lots were selected, however, for qualitative analysis, and the results of the analyses are given in the following table:

Qualitative analyses of specimens of niter from a locality near Soldier, Idaho.

No.	Cl.	SO_4.	CO_3.	NO_3.	K.	Na.	Ca.	Mg.	Essential composition.
1...	Trace.	None.	None.	Much.	Much.	Fair..	Some.	Very little.....	KNO_3, some $NaNO_3$, and $Ca(NO_3)_2$.
2...	...do...	Some.	...do...	...do...	...do...	...do...	...do...	.....do........	KNO_3, with some $NaNO_3$ and $Ca(NO_3)_2$.
3...	None.	None.	...do...	...do...	...do...	Some.			KNO_3.
4...	Trace.	...do...	...do...	...do...	...do...	Fair..	Some.	Small amount	Same as Nos. 1 and 2.

1. Finer material, inclosed in paper sack, more or less distinct from the other samples.
2. Finer material, that came loose in large sack containing all the samples.
3. Filling dug out of cavity on side of large piece of rock.
4. Nitrate from a pocket on side of a large rock specimen.

The Soldier deposits, so far as represented by the samples examined, appear to be largely free from chlorides and sulphates, and to consist mainly of potassium nitrate, with less amounts of sodium and calcium nitrates. It was not deemed advisable to make expensive quantitative determinations of the material submitted because of the condition of the samples and the lack of definite knowledge regarding their field relations.

EXTENT AND VOLUME OF THE NITRATES.

The Jump Creek deposit lies about 10 miles east of the Sucker Creek locality. According to Mr. Sullivan, indications of nitrate deposits occur between these two places, and have been found by others as far as 150 miles to the west of Sucker Creek, but the showing at Sucker Creek is better than that farther west. Soldier, Idaho, is about 120 miles east of the Sucker Creek locality. The occurrences of the nitrates above mentioned are all associated with rhyolites. Nitrate deposits in rhyolites occur at several places in Nevada and Utah.[1] The rhyolites seem to be widely distributed and to carry niter in many places, though niter is by no means confined to rhyolitic rocks. The Homedale district is therefore probably only a part of a much larger niter-bearing area, in which locally, as at Sucker Creek, the niter occurs in notable amounts.

The mode of occurrence of the nitrate in the Homedale district is described on pages 20–25. The little veinlets that contain the nitrate form only a small part of the whole mass in the zones where the nitrates occur—probably not more than 1 per cent—and the same veinlets carry other substances than nitrates, as is shown by the analyses. When the rock fragments are picked down from the cliff face at any of the prospects described, fresh veinlets are exposed, similar in character, number, and thickness to those previously found. How far into the rock this condition continues it is impossible to say from present data, as none of the prospects have penetrated more than 3 or 4 feet from the cliff face. The present evidence does not preclude the possibility of finding an increase in the size and number of the nitrate-bearing veinlets, or perhaps even large veins, when the rock is opened further. There seems, however, little likelihood of any marked increase in richness within the interior of the rock mass. On the contrary, it appears more probable that the richest parts of the deposit are those already exposed in the faces and along the bases of the cliffs and that the material will be found to grow gradually leaner and perhaps to disappear altogether as the rock is penetrated. Whatever may have been the mode of origin of the material, it probably owes its present position to the action of percolating waters on the one hand and to evaporation on the other. On that supposition the concentration of the deposit would naturally be greatest at or near the surface, where evaporation takes place. However, no positive statement can be made until more work has been done in opening the veinlet-bearing zones, both laterally and vertically.

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[1] Gale, H. S., Nitrate deposits: U. S. Geol. Survey Bull. 523, pp. 16-25, 1912.

OTHER SALTS OF THE HOMEDALE DISTRICT.

DISTRIBUTION AND GEOLOGIC RELATIONS.

In secs. 11 and 12, T. 23 S., R. 46 E. of the Willamette meridian, Oregon (see fig. 2), east of Sucker Creek, there is a group of low rounded hills, some of which are bare of vegetation and are covered with dried clay comminuted into tiny angular fragments that are easily scraped aside by the foot. From 4 to 6 inches below the surface there is a white salt that is efflorescent and dried in the upper 3 or 4 inches but damp and coarsely crystalline below and 2½ feet or more thick. This material is somewhat impregnated by clay and is exposed in a group of prospect pits which have been opened to a depth of 2 to 3 feet. The material exposed beneath the salt bed is a fine massive drab clay. A placer claim of 120 acres, called the American placer, has been located on these deposits by the American Fertilizer Co. Samples of the efflorescent salt and of the unmodified salt were collected for analysis.

On Jump Creek, west of the McCloud ranch, there is a series of three low, rounded barren knolls just outside of the canyon. These knolls have been taken up as saline deposits by D. J. Sullivan and others under the name Claytonia claims. Claytonia claim No. 1 was visited by the writer in company with Mr. Sullivan. Its location with reference to established land surveys was not known at the time of the visit, as it had not then been surveyed. Its approximate location is shown in figure 2. The saline deposit here is similar in character and mode of occurrence to the American placer, described above. At the Claytonia No. 1 there is a prospect about 8 feet long, 5 feet wide, and 4 feet deep at which the following section was measured:

Section at Claytonia No. 1 claim, Jump Creek, Idaho.

	Ft.	in.
Clay, drab, broken, gypsiferous		5
Salt deposit, damp, sugary, coarsely crystalline, white and efflorescent in upper 2 or 3 inches		10±
Sand, yellow, fine, saline, gypsiferous		4
Sand, gray, fine, powdery, with ferruginous streaks near base, gypsiferous	1	6
Gypsum seam		2
Clay, gray, compact, gypsiferous to bottom of cut	1	6
	4	9

Samples of the salt and the two sandy zones beneath were taken for analysis. According to Mr. Sullivan, these deposits continue more or less intermittently outside the hills and up Sucker Creek as far as Huntley's ranch.

As mapped by Drake,[1] the above-mentioned deposits fall in the group of later lake beds—the Idaho formation, of Pliocene age—that occupies the Snake River valley and regions east of the Owyhee Range up to elevations of 3,000 feet. The Idaho formation is described in general terms as less indurated than the Payette formation (earlier lake beds), and as consisting of very soft, brilliantly white sandstones, changing in places to compact gypsiferous clay. In a few places gravel and fluviatile sand are also present. The following section is given for a point in a bluff not far from the Claytonia claims:

Section of bluff 3 miles west of Snake River, north of Squaw Creek, Idaho.

	Feet.
At top, sand and gravel, probably Pleistocene, resting on the lake beds	14
Exceedingly well and evenly stratified light-gray to buff clay, in thin beds and interbedded with many thin streaks of gypsum and gypsiferous sand	190

At the American placer the saline deposits seem to follow the contour of the hill. No bedding other than the line between the salt deposit and the underlying clay was observed in the prospects examined. The impression gained here was that the deposit was of secondary character, formed by capillary activity of impregnated waters and evaporation. At the Claytonia No. 1 claim bedded sands and clays were observed beneath the saline deposit. Though the surface appearance and the character of the two deposits are much alike, the bedding relations, so far as observed, suggest that the Claytonia deposit may be primary, having been originally deposited with the other sediments. A more extended examination of the region is needed before a final decision as to the primary or secondary nature of the deposits can be made.

ANALYSES.

Qualitative analyses of the five samples collected from the two localities were made, and are given on page 26 under the numbers S. C. 8a, 8b, 9, 9a, and 9b. The deposits appear to consist essentially of sodium and magnesium sulphates, with more or less sodium chloride—in other words, of a mixture of Glauber's and Epsom salts with common salt. The fact that practically all the deposit effloresces to a white powder on exposure to the drying action of the air indicates that little if any of the material is in the form of the mineral blœdite, a hydrous sulphate of sodium and magnesium, for this mineral does not alter on exposure to the air like the crystals of hydrous sodium sulphate. It was not deemed advisable at this time to incur the expense of quantitative determinations of the samples.

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[1] Lindgren, Waldemar, and Drake, N. F., U. S. Geol. Survey Geol. Atlas, Silver City folio (No. 104), 1904.

UTILIZATION OF THE NITRATES.

It has been pointed out in connection with the Homedale deposit that the veinlets which contain the niter and associated salts form a very small percentage of the rock mass in the niter-bearing zones. If it were practicable to leach the rock and remove the soluble salts without handling the rock itself, something might be done commercially with the niter. From the constitution of the country rock, however, it seems that little could be done without moving a relatively large amount of the rock. The cost of these operations and the necessary equipment, together with the uncertainty regarding the continuation of the deposits within the rock mass, would seem to allow little hope of successful commercial development.

The Homedale and Soldier deposits may be taken as types of material from localities in many parts of the country, ranging all the way from Oregon to Texas, from which specimens have lately been received by the Geological Survey. The niter occurs on the surface and in cracks, forming in places rich veins in considerable quantity, but at no place yet examined has this superficial material seemed to lead to deposits extensive enough to have commercial value. Investigations should be continued in the hope that a commercially valuable deposit may be found. At the present time, however, the outlook is not very promising.

UTILIZATION OF THE SULPHATES.

An account of certain deposits of sodium sulphate and the market conditions affecting them has recently been given by Gale.[1] There is at present no considerable market for sodium sulphate, or what is known in trade as "salt cake," which is the product of the first step in the Le Blanc process for the manufacture of sodium carbonate from sodium chloride. In this process salt cake is produced by the decomposition of sodium chloride with sulphuric acid, hydrochloric acid being a valuable by-product. At present, however, the Le Blanc process has been almost entirely displaced by the ammonia process for the manufacture of soda, at least in the United States. Glauber's salt[2] ($Na_2SO_4.10H_2O$) is manufactured for a few purposes, chiefly for medicinal use and for freezing mixtures. A considerable quantity is obtained from the residuals of the Stassfurt salts. In the manufacture of practically all qualities of glass, except lead glass, salt cake is superior to soda ash because it is cheaper per unit of alkali and because, owing to the higher temperature at which the glass furnaces work when using salt cake, a higher percentage of silica can

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[1] Gale, H. S., Sodium sulphate in the Carrizo Plain, San Luis Obispo County, Cal.: U. S. Geol. Survey Bull. 540, pp. 428-433, 1914.

[2] Thorpe, E., Dictionary of applied chemistry, vol. 5, pp. 21, 27, 581, 1913.

be used, thus again cheapening the cost and also producing a harder and more durable glass. Sodium sulphate is also used in the manufacture of ultramarine, which in turn has a wide use in a variety of manufactures because of its brilliancy as a body color and its high coloring power. Sodium sulphate is also used in the general processes of dyeing and coloring. Quotations on sodium sulphate in current trade journals range from 55 to 65 cents per 100 pounds for glassmaker's salt cake and 60 to 75 cents per 100 pounds for Glauber's salt in barrels. This is equivalent to $11 to $15 a short ton.

Magnesium sulphate is the purgative principle of many bitter spring waters and, as Epsom salts, has a considerable use in medicine. It is also used in warp sizing and weighting in cotton mills. The magnesium sulphate of commerce is derived chiefly from the kieserite ($MgSO_4+H_2O$) of Stassfurt. It is also manufactured to some extent in the United States from magnesite and dolomite. There is at present no large market for magnesium sulphate. Quotations on Epsom salts in current trade journals range from 1 to 1½ cents a pound in bags or barrels. This is equivalent to $20 to $30 a short ton.

In view of the present moderate or slight demand for the sulphates of sodium and magnesium and the fact that this demand is largely met in by-products derived from the manufacture of soda and potash salts, there seems little likelihood of the development on a commercial scale of mixed deposits such as those near Homedale unless they should prove to be present in much greater abundance than now seems probable. There is probably not enough sodium chloride in the deposits to warrant their development as a source of common salt.

GEOGRAPHY AND GEOLOGY OF THE HOMEDALE REGION.

PREVIOUS WORK.

Land surveys of the entire district discussed in this report have been made, and plats of the several townships are on file in the General Land Office, Washington, D. C. A large part of this work is relatively recent, the dates of the surveys ranging from 1878 to 1914.

Much of the area has been included in topographic surveys by the Geological Survey and three maps, covering the Nampa and Silver City quadrangles, Idaho, and the Mitchell Butte quadrangle, Oreg., have been issued. The junction point of the three quadrangles lies in latitude 43° 30′ N., longitude 117° W., about 9 miles S. 25° W. of Homedale.

The entire district has been discussed by Russell[1] in earlier reports of the Geological Survey, but these were reconnaissance reports that covered a broad area, so that they furnish few details bearing directly on the nitrate district. The particular object of Russell's work was the investigation of ground-water conditions, but it throws considerable light on the general geology of the region as a whole.

Parts of the district and some adjacent regions have been made the subject of more detailed geologic surveys. The Nampa and Silver City folios of the Geologic Atlas[2] issued by the Survey contain many details relating to the geology of the eastern part of the area, and much of this information is directly applicable to the unmapped western part. Oil and gas investigations have also been undertaken by the Survey in regions adjacent to the nitrate district.[3]

GEOGRAPHY.

LOCATION AND ACCESSIBILITY.

Homedale lies in the northwestern part of Owyhee County, Idaho, on Snake River near the State line. A branch railroad connects it with Nyssa, Oreg., a junction point, 20 miles to the north, on the Oregon Short Line Railroad. Stage connections are maintained with Caldwell, Idaho, also on the Oregon Short Line Railroad, about 12 miles in a direct line N. 75° E. from Homedale. Although more or less mining has been done in the hills bordering the Snake River valley in this region, the interest of the valley towns, including Homedale, is chiefly agricultural, and water is available through several irrigation projects. Homedale lies in the Gem irrigation district. At the time of the writer's visit the town comprised about 280 voters, including both sexes.

George D. Huntley's ranch, near which the nitrate deposits of Sucker Creek were first found, is in the SE. ¼ SE. ¼ sec. 29 and the NE. ¼ NE. ¼ sec. 32, T. 24 S., R. 46 E. Willamette meridian, in Malheur County, Oreg. Huntley's ranch has recently been sold to D. J. Sullivan. This part of the district is not included in the quadrangles named above but lies 4 or 5 miles west of the Silver City quadrangle.

A preliminary railroad survey along Sucker Creek to the southwest and south from Homedale has already been made. In the event of the completion of this railroad the agricultural, grazing, and mineral lands of the district will be readily accessible from the main line to the north.

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[1] Russell, I. C., U. S. Geol. Survey Bull. 199, 217, 252; Water-Supply Paper 78.

[2] Lindgren, Waldemar, and Drake, N. F., U. S. Geol. Survey Geol. Atlas, Nampa folio (No. 103); Silver City folio (No. 104), 1904.

[3] Washburne, C. W., Gas and oil prospects near Vale, Oreg., and Payette, Idaho: U. S. Geol. Survey Bull. 431, pp. 26-57, 1911.

TOPOGRAPHY.

The hills south of Snake River in this district are the lower foothills of the north end of the Owyhee Range. The country here is essentially a submaturely dissected high plain that slopes gently northward and is underlain by lavas with associated tuffs and lake beds. Flat-topped strips of hills with intervening valleys extend generally north or northeast. Where the valleys are cut in tuffs or lake beds they broaden, but where they encounter massive sheets of lava they form sharp-featured canyons with precipitous or even overhanging walls 250 to 300 feet high. The highest land in the part of the district examined does not much exceed 4,700 feet, and the lowest elevation, where Snake River leaves the district, is a little less than 2,200 feet, so that the maximum relief is about 2,500 feet. Some of the deeper canyons not included in the district have walls that rise steeply from 1,000 to 1,800 feet in height.

In the immediate vicinity of Snake River and for 8 miles or more to the south the country is nearly flat. It has an elevation of 2,300 to 2,400 feet and rises gently to 2,500 feet at the base of the hills. Near the river the surface soil is sandy, but a mile or two back from the river the surface is covered with a fine-textured, compact whitish soil that in the roads is cut into a fine, impalpable dust 2 to 6 inches deep. When wet this dust is transformed into a sticky mud that cakes wheels and impedes travel.

DRAINAGE.

All the drainage of this district is tributary to Snake River, which flows through the northern part. The volume of the Snake varies with the season, being highest in June and lowest sometime in the winter or early in the spring. The flow probably ranges from about 8,000 second-feet at the low stage to about 40,000 second-feet at the high stage. The river at Homedale flows between bluffs about 30 feet high, at a grade of about 5 feet to the mile. The river here is probably still eroding its channel, for low-lying islands in the vicinity of Homedale are seldom flooded.

In the district under discussion only two minor streams need be mentioned. These are Sucker and Jump creeks. Sucker Creek rises well back in the range toward Silver City and flows 40 miles or more before joining the Snake. It is a permanent stream of small volume. Jump Creek is much shorter, and its waters generally sink in the plain before reaching Snake River.

CLIMATE.

This part of the Snake River valley lies in the arid belt, and its climate and vegetation are closely allied with those of the Great Basin. The Pacific meteorologic influences are strongly felt, so that the climate is comparatively mild. The precipitation is somewhat greater than in the Great Basin. In the valleys the temperature may exceed 100° F. for a few days in summer; in winter it rarely sinks to 0° F., though an occasional cold wave may force the temperature considerably below zero for a short time. At Boise the mean annual temperature is 50° to 53° F. The winds are generally from the southwest, but are seldom very strong. They often carry much dust.

It is claimed by the residents of Homedale that they have the least rainfall in the State. The normal annual rainfall at Nampa is reported to be 10.06 inches. Most of this falls between September 1 and June 1 and is fairly well distributed through these months. In ordinary winters but little snow falls in the valleys, and this does not long remain on the ground. In the hills south of the district the rainfall is somewhat greater, and snow may linger in protected places far into the summer. Springs in the hills are numerous.

VEGETATION AND INDUSTRIES.

The vegetation is scanty and is mainly sagebrush. The soil is said to be highly productive when irrigated and to be adapted for the growth of fruits, vegetables, and grain. The hills support many sheep that in the winter are fed in the valley. It is stated that some 50,000 sheep are wintered in the valley in the vicinity of Homedale.

GEOLOGY.[1]

IGNEOUS ROCKS.

The rocks of the southern part of the district are massive rhyolites that form part of the great body of rhyolite which surrounds the central part of the Owyhee Mountains. The rhyolite was outpoured in viscous masses over uneven surfaces, so that its thickness varies, but in the region covered by this report it is about 1,500 feet thick. When fresh the rhyolite is characterized by rough plateaus bordered by abrupt and rocky bluffs, and the faces of many of the cliffs present a rough columnar structure. In the canyons curious spires and pinnacles are produced by differential weathering. Where the rhyolite is softened by alteration it forms sloping ridges.

The appearance of the rhyolite is similar to that seen in most of the areas of that rock found in the West. The rock in general is compact, hard, and very resistant to weathering. Its color is grayish, greenish, yellowish, or brownish in different shades, varying greatly and abruptly. Practically all the varieties belong to the structural group comprising felsophyric rhyolite. These rocks are rich in silica and alkalies.

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[1] See U. S. Geol. Survey Geol. Atlas, Nampa folio (No. 103) and Silver City folio (No. 104), 1904.

The writer has examined several slides of the rhyolite from Sucker Creek in the vicinity of the nitrate deposits, including a green variety that first appears in the canyon about 3 miles north of Huntley's ranch. The slides all showed the rock to be rhyolite of the usual type. The rhyolite in Sucker Creek is marked at several localities by a strongly developed flow structure that is steeply inclined or nearly vertical, with brecciation and the development of folds. (See Pls. II, III.)

From their relations to the lake beds which are in part derived from them and overlie them the rhyolites are believed to be of Eocene age.

Other igneous rocks, both earlier and later, occur in the region to the south and southeast of this district, but they have little bearing on the subject of this report.

SEDIMENTARY ROCKS.

The sedimentary rocks of the district are Tertiary lake beds and Quaternary stream deposits. The lake beds form gently sloping plateaus of almost horizontally bedded sediments which by various features show that they were for the most part deposited in a large body of fresh water. The persistently fine-grained character of the sediments, the absence of cross-bedding, such as would indicate strong currents, and the common occurrence of gypsiferous sands are regarded as evidence of lacustrine origin. Fluviatile deposits were naturally formed in many places contemporaneously with the recession of the lakes, but these are of less extent. In some places later thin basalt flows are intercalated in the uppermost lake beds. The sediments are predominantly sandy materials, more or less consolidated, but also with subordinate amounts of clay and volcanic tuffs. Gritty sandstones, generally micaceous, are common. Conglomerates occur also but are rarely coarse. They consist chiefly of granite pebbles, but at some places rhyolitic and basaltic pebbles are found. Silicified wood and opalized wood are common. In many places the lake beds are of a dazzling white color, but the clays in some localities are decidedly yellow and in others brownish or greenish brown. The brownish clays are usually lignitic, and the greenish-brown clays and sands appear to be in part basaltic tuffs.

Near the point where the stage road from Caldwell to Jordan Valley crosses Sucker Creek, near the State line, at an elevation of 4,800 feet, an extensive flora was found in horizontal lake beds and proved to be identical with that of the Payette formation near Boise. The flora is referred by Knowlton to the upper Eocene. Occasionally mammalian remains are also found in the lake beds. A later group of lake beds in the Snake River valley, which show different petrographic characters and a later fauna, are referred to the Idaho formation, of Pliocene age. These beds are not, however, easily differentiated in appearance from the older beds.

The lake beds are more or less dissected by Sucker Creek and other streams, but the interstream surfaces have not been generally lowered.

Quaternary deposits are present in the form of local stream fans that spread over the lake beds from both sides of the range in a thin sheet of angular gravel and in earlier and later terrace gravels along the Snake River valley, extending back toward the hills. These deposits merge into one another and are in many places not distinctly separable. Recent alluvium forms a narrow strip along the present valley bottom of the Snake.

STRUCTURE.

The rhyolites and lake beds dip away gently from the granitic core of the Owyhee Range, so that on the west side of the range, where the nitrate field lies, the dips are generally westward and the strike somewhat west of north. In some localities the beds are horizontal or only slightly inclined. The structure of the distorted beds of lava along Sucker Creek near Huntley's ranch is regarded as a feature of the original outpouring of the viscous lava rather than a result of subsequent deformation. (See Pl. II.)

There appears to be some evidence of faulting along Sucker Creek, however. About 3½ miles north of Huntley's ranch brown lake beds on the east side of the canyon lie opposite purplish rhyolite on the west side and purplish-gray rhyolite on the east side lies opposite green rhyolite on the west side, while small masses of green rock still cling to the vertical or overhanging wall on the east side. The green rhyolite is in part tuffaceous and bears evidence of some hydrothermal action.

GEOLOGIC HISTORY.

According to Lindgren and Drake[1] an early Tertiary epoch of erosion was followed by outbursts of rhyolite and basalt and the deposition of the lake beds composing the Payette formation, which near the margins of the basin had a probable thickness of about 2,000 feet. The Payette formation is probably of Eocene age. The deposition of the Payette beds was followed by an apparently short and active epoch of erosion during which the rivers cut down through the lake beds to the same depth that they have to-day. Causes not yet known checked this erosion and produced a lake of smaller dimensions and shallower depth than the Payette lake. In this the beds of the Idaho formation with their Pliocene fauna were deposited.

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[1] U. S. Geol. Survey Geol. Atlas, Silver City folio (No. 104), 1904.

The draining of this lake is considered to have closed the Tertiary period. Since then the region has been dry land, and slow, frequently checked erosion has cut into the lake beds and deposited the material in extensive areas of Quaternary sand and gravel.

NITRATE DEPOSITS IN GENERAL.

The subject of nitrates with special reference to deposits in the United States has been reviewed by H. S. Gale.[1] Nitrate salts are widely distributed in several forms. They are found in all fertile soils in small amounts, and it has recently been argued that they occur in sedimentary rocks from which certain soils have been derived.[2] The nitrate salts thus distributed are not considered recoverable for commercial use except under some unusual condition. They are also found in more concentrated form in arid climates as in the well-known extensive deposit in Chile, the so-called "niter spots" of Colorado and Utah, and other scattered deposits in arid portions of the West. The general solubility of nitrate salts is so great that they do not accumulate in moist climates except in protected places such as caves and beneath overhanging cliffs. The nitrates are usually white crystalline salts with a pronounced taste, the character of which varies with the base with which the nitric acid is combined.

SODIUM AND POTASSIUM NITRATES.

COMPOSITION AND GENERAL PROPERTIES.

The nitrates most common in occurrence as well as most important in commerce are those of sodium and potassium.

Sodium nitrate, sometimes called soda niter, cubic niter, or Chile saltpeter, has the same crystalline form and cleavage as calcite—that is, it is rhombohedral. The angles of the rhombohedra are nearly right angles, whence the name cubic niter. The pure salt forms colorless, transparent crystals of the composition $NaNO_3$, in which nitrogen pentoxide constitutes 63.5 per cent and soda 36.5 per cent. Sodium nitrate deflagrates on charcoal and hence will flare when thrown upon burning coals, though less violently than potassium nitrate. The sodium combined in it imparts a strong yellow color to the flame. Sodium nitrate is deliquescent and very soluble in water. Its solubility increases with increase of temperature, 100 parts of water dissolving about 70 parts at 0° C., about 80 parts at 15°, and 125 parts at 68°.

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[1] Gale, H. S., Nitrate deposits: U. S. Geol. Survey Bull. 523, 1912.

[2] Stewart, R., and Petersen, W., The nitric nitrogen content of the country rock: Utah Agr. Coll. Exper. Sta. Bull. 134, 1914.

Potassium nitrate, also called niter or saltpeter, in crystalline form is orthorhombic. Its composition is KNO_3, in which nitrogen pentoxide constitutes 53.5 per cent and potash 46.5 per cent. Potassium nitrate occurs naturally as thin white granular crusts or masses or in minute needle-form crystals, and as a thin coating on earth, walls, and rocks. The pure salt is transparent and crystalline and has a cooling, rather sharp saline taste. It deflagrates strongly when thrown on burning coals. The potassium combined in it imparts a strong violet color to the flame. In impure material this color is often masked by the yellow of sodium, but the violet color of potassium may be recognized if the flame is viewed through blue glass, which shuts out the yellow color. The salt dissolves readily in water and is not altered by exposure.

A piece of hot charcoal or the glowing tip of a burnt match will glow at white heat in contact with sodium or potassium nitrate, and the nitrate will tend to fuse and burn with a sputtering flame. Also a piece of paper moistened in a solution of one of these nitrates and then dried will burn with a sputtering flame.

CHILEAN DEPOSITS.

The nitrate deposits in the deserts of Atacama and Tarapaca, Chile, occur in beds having a maximum thickness of about 6 feet. They usually occur near the surface but in places lie beneath an overburden of 30 feet. The nitrates are never pure but are mixed with sodium chloride and other salts and impregnated with insoluble earthy matter. The crude mixture may contain as much as 60 or 70 per cent of sodium nitrate, but 50 per cent material is considered high grade. Material containing less than 10 per cent is too poor to be mined at a profit now.[1] Much has been written about the Chilean deposits, but further reference to them can not be made here. A partial bibliography of them is included in Bulletin 523.

USES OF SODIUM AND POTASSIUM NITRATES.

Sodium nitrate is used for many of the purposes for which the potassium salt is employed, but its hygroscopic nature makes it unavailable for the manufacture of gunpowder or fireworks. For making nitric acid, for supplying that acid in sulphuric-acid manufacture, and for use as a fertilizer it has entirely replaced potassium nitrate. It is also the principal source of the potassium salt, which is obtained from it by double decomposition with the potassium chloride of Stassfurt.

Potassium nitrate (niter or saltpeter) is used chiefly in the manufacture of gunpowder or other explosives but also in fireworks, in

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[1] Ross, W. H., The origin of nitrate deposits: Pop. Sci. Monthly, August, 1914, pp. 134-145.

lucifer matches, for curing meat, for the manufacture of certain kinds of glass, for flux in metallurgic assays, for dyeing, and in medicine.

According to Pennock[1] 535,820 tons of sodium nitrate was imported into the United States in 1910 from Chile. This material was utilized in various industries, as follows:

Consumption of nitrate of soda from Chile in 1910.

	Per cent.	Tons.[a]
Explosives	41	219,686
Fertilizers	13	69,657
Dyestuffs	12	64,298
General chemicals	10	53,582
Nitric acid	9	48,224
Sulphuric acid	6	32,149
Glass	4	21,433
Unaccounted for	5	26,791
	100	535,820

[a] Computed from percentages given by Pennock.

PRICES OF NITRATES.

The total imports of nitrates by the United States in 1913 and 1914, together with the reported value, are given in the following table:

Imports of nitrates, 1913–14.[a]

	1913			1914		
	Quantity.	Value.	Value per ton.[b]	Quantity.	Value.	Value per ton.[b]
Nitrate of soda.........long tons..	625,862	$21,630,811	$34.56	543,715	$15,228,671	$28.01
Nitrate of potash (crude).pounds..	9,876,910	262,575	59.49	2,229,856	74,743	73.92

[a] Monthly Summary of Foreign Commerce of the United States, December, 1914.
[b] Computed from totals given.

According to recent statistics,[2] there has been for the last few years a marked increase both in the quantity and in the price of imported nitrates. During the year 1914, however, there was a noticeable reduction in the importations of both sodium and potassium nitrates. Sodium nitrate has fallen in price, but potassium nitrate has shown a marked increase. Doubtless these changes in the normal rate of advance are due to the disturbance in trade caused by the great European war.

ORIGIN OF THE HOMEDALE NITRATES.

A review of the hypotheses of the formation of nitrates, together with an account of the processes of nitrification, is given in Survey Bulletin 523. An interesting summary of the various modes of

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[1] Pennock, J. D., Jour. Ind. and Eng. Chem., vol. 4, p. 173, 1912.
[2] U. S. Geol. Survey Mineral Resources for 1913, pt. 2, p. 105, 1914.

occurrence of nitrates and the many explanations of their origin is given in a recent paper by Ross.[1]

The most prevalent views of the origin of niter require the presence of organic matter in some form and the action of micro-organisms. In the descriptions of cave deposits given in Bulletin 523 it is shown for some deposits and assumed for others that bacterial activity upon organic matter in the form of animal excreta has caused the development of the nitrates.

The Homedale deposit and probably the Soldier deposit also belong to the general group classed as cave deposits. There is, however, little direct evidence of the former presence of animal excreta at the Homedale deposit. There may indeed be inconspicuous amounts of such material present in cracks or openings of the rocks above and more or less remote from the deposit. Bacterial action would develop nitrates from such material, and percolating waters penetrating the more shelly and fissured zones would carry these soluble salts to favorable places for their concentration by evaporation. Such places would be the faces of cliffs protected from rain or melting snow, the walls of shallow caves, and crevices leading to these places. In a similar manner organic matter disseminated through the soil above the cliffs might, through bacterial action, furnish nitrates which could be removed and concentrated as above outlined. It is probable that organic matter in one or both the forms mentioned has been the chief source of the nitrate deposits near Homedale and at Soldier. There are, however, other possible sources that deserve some discussion.

The occurrence of nitrates in association with igneous rocks at numerous places in the West has led many observers to the suggestion that the nitrogen of these deposits may have had a volcanic source. This idea was forcibly impressed on the writer by the sight of the disturbed structures in the rhyolite and the spherulitic, vesicular, and shelly zones in the rock in the immediate vicinity of the deposits near Homedale (Pls. II, III). The suggestion was strongly conveyed that the rhyolite at this place may have been near the site of a former vent or point of eruption and that volcanic emanations may have played some part in the supply of the nitrogen now forming the nitrates.

The presence of ammonium chloride in the fumaroles of a number of volcanoes, notably Vesuvius, has long been known. Nitrogen is also recognized among the gases that escape in volcanic eruptions. Considerable discussion, which has been well summarized by Clark,[2] has taken place with regard to the source of this nitrogen. The idea that the nitrogen originates from organic matter, such as vegetation, with which the lava comes into contact, or from the nitrogen of the

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[1] Ross, W. H., The origin of nitrate deposits: Pop. Sci. Monthly, August, 1914, pp. 134–145.

[2] Clarke, F. W., The data of geochemistry, 2d ed.: U. S. Geol. Survey Bull. 491, pp. 248 et seq., 1911.

air does not seem well sustained. Although Lacroix[1] notes the production of ammonium chloride by one of the lava flows in covering cultivated or inhabited ground during the eruption of Vesuvius in April, 1906, many occurrences of ammonium chloride are such as to preclude the presence of organic matter. Although special instances like that cited by Lacroix may occur, the nitrogen of the lava at volcanic eruptions is regarded as clearly an original constituent and not of organic origin. It has been argued that nitrides within the earth may be the source of the nitrogen. Under the assumption that the nitrogen of the Homedale and other similar regions might have had a volcanic source, it might be supposed that ammonium chloride formerly present in the rocks had by bacterial or other agencies been changed into nitrates and localized by percolating waters and evaporation. At least two factors more or less unfavorable to this view may be cited. (1) The analyses of the nitrate samples from Homedale and Soldier show no trace of the presence of boron, which might perhaps be expected under the volcanic assumption, as the volcanic origin of many borate deposits seems fairly well established; (2) several changes of climate have undoubtedly occurred since the outpouring of the rhyolite, and it seems probable that during the moister climatic epochs much of the ammonium chloride and its derived salts would have been removed by leaching, although in this case much would depend on the manner of the original distribution of the ammonium chloride.

Another fact, which, so far as the writer is aware, has not been considered in this connection, should be mentioned. It has long been known that nearly if not quite all rocks, on heating to redness, give off large quantities of gas. This fact was noted by Priestly as early as 1781. It was at first thought that the gases were occluded in the rocks, but it has recently been shown that igneous action may generate them from the solid minerals themselves.[2] R. T. Chamberlin[3] cites many analyses of gases derived by heating powdered rock in a vacuum. Most of the common rock types were included in his experiments, and practically all the evolved gases were shown to contain nitrogen.

With regard to these gases the attention of investigators thus far has centered chiefly on their origin. The present evidence points strongly to nitrides as the source of at least a part of the nitrogen. Inasmuch as nitrogen is evolved from many kinds of rocks, as is shown by Chamberlin's analyses, it would seem that nitrides yet

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[1] Lacroix, A., L'éruption du Vesuve en avril 1906; II^{me} partie, Les fumerolles et les produits de l'éruption: Rev. gén. sci., vol. 17, pp. 923–936, Nov. 15, 1906.

[2] Clarke, F. W., op. cit., pp. 261–265.

[3] The gases in rocks: Carnegie Inst. Washington Pub. 106, 1908.

unrecognized may be widely distributed through the rocks that make up the outer crust of the earth. The gases thus far examined have all been obtained at relatively high temperatures—360° to 850° C. In the presence of water vapor or hydrogen ammonia gas is developed from a nitride. It would be interesting to discover if possible whether similar gases are evolved from rocks in the slow processes of weathering and subaerial denudation and whether these conditions and the influence of bacteria might produce nitrates which would be carried in solution and concentrated at favorable places by evaporation.